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China Startup – a Thorium-powered Molten-salt Reactor

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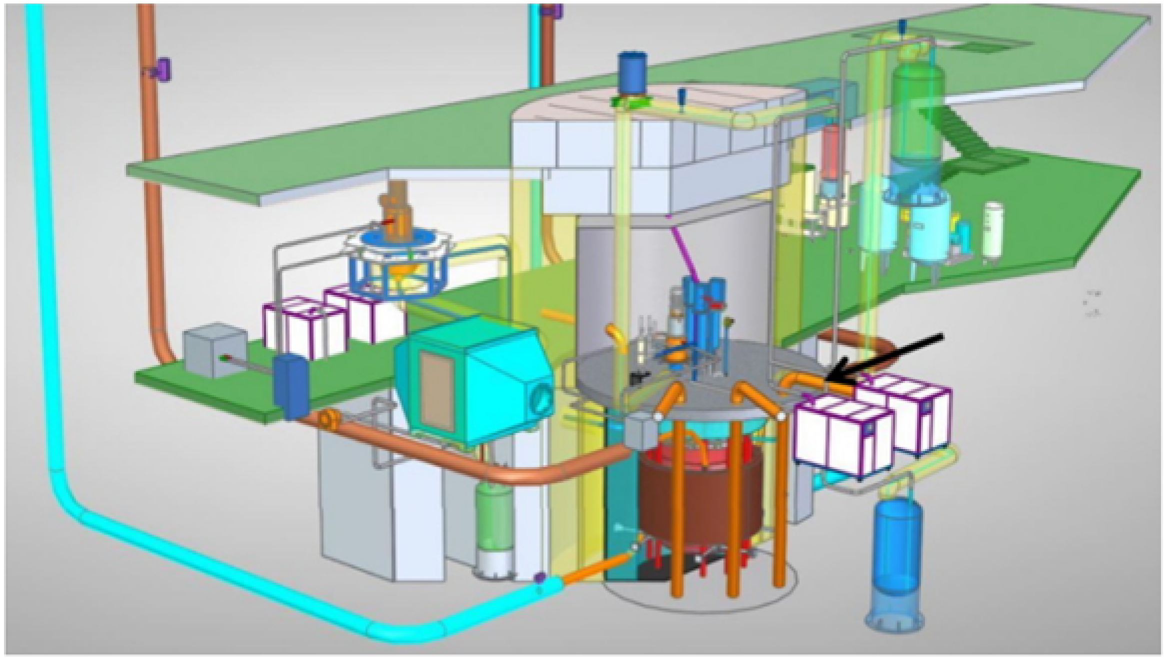
China Startup – a Thorium-powered Molten-salt Reactor

(WNN) The Shanghai Institute of Applied Physics (SINAP) – part of the Chinese Academy of Sciences (CAS) – has been given approval by the Ministry of Ecology and Environment to commission an experimental thorium-powered molten-salt reactor following a three-year construction effort. The TMSR Centre at SINAP at Jiading, Shanghai, is responsible for the project.

The Shanghai Institute of Applied Physics (SINAP) - part of the Chinese Academy of Sciences (CAS) - has been given approval by the Ministry of Ecology and Environment to commission an experimental thorium-powered molten-salt reactor, construction of which started in Wuwei city, Gansu province, in September 2018.



A cutaway of the TMSR-LF1 reactor (Image: SINAP)

In January 2011, CAS launched a CNY3 billion (USD444 million) R&D program on liquid fluoride thorium reactors (LFTRs). Another name for the technology is as a thorium-breeding molten-salt reactor (Th-MSR or TMSR).

The thorium [molten salt reactor] nuclear energy system (TMSR) is designed for thorium-based nuclear energy utilization and hybrid [nuclear energy application], based on a liquid-fueled thorium molten salt reactor (TMSR-LF) and a solid-fueled thorium molten salt reactor (TMSR-SF).

China claims to have the world's largest national effort on thorium fueled MSR reactor designs and plans to assert global intellectual property rights on the technology. If the TMSR-LF1 proves successful, China plans to build a reactor with a capacity of 373 MWt by 2030. (Reference: Molten Salt Reactors – WNA)

The TMSR-LF1 will use fuel enriched to under 20% U-235, have a thorium inventory of about 50 kg and conversion ratio of about 0.1. A fertile blanket of lithium-beryllium fluoride (FLiBe) with 99.95% Li-7 will be used, and fuel as UF_4.

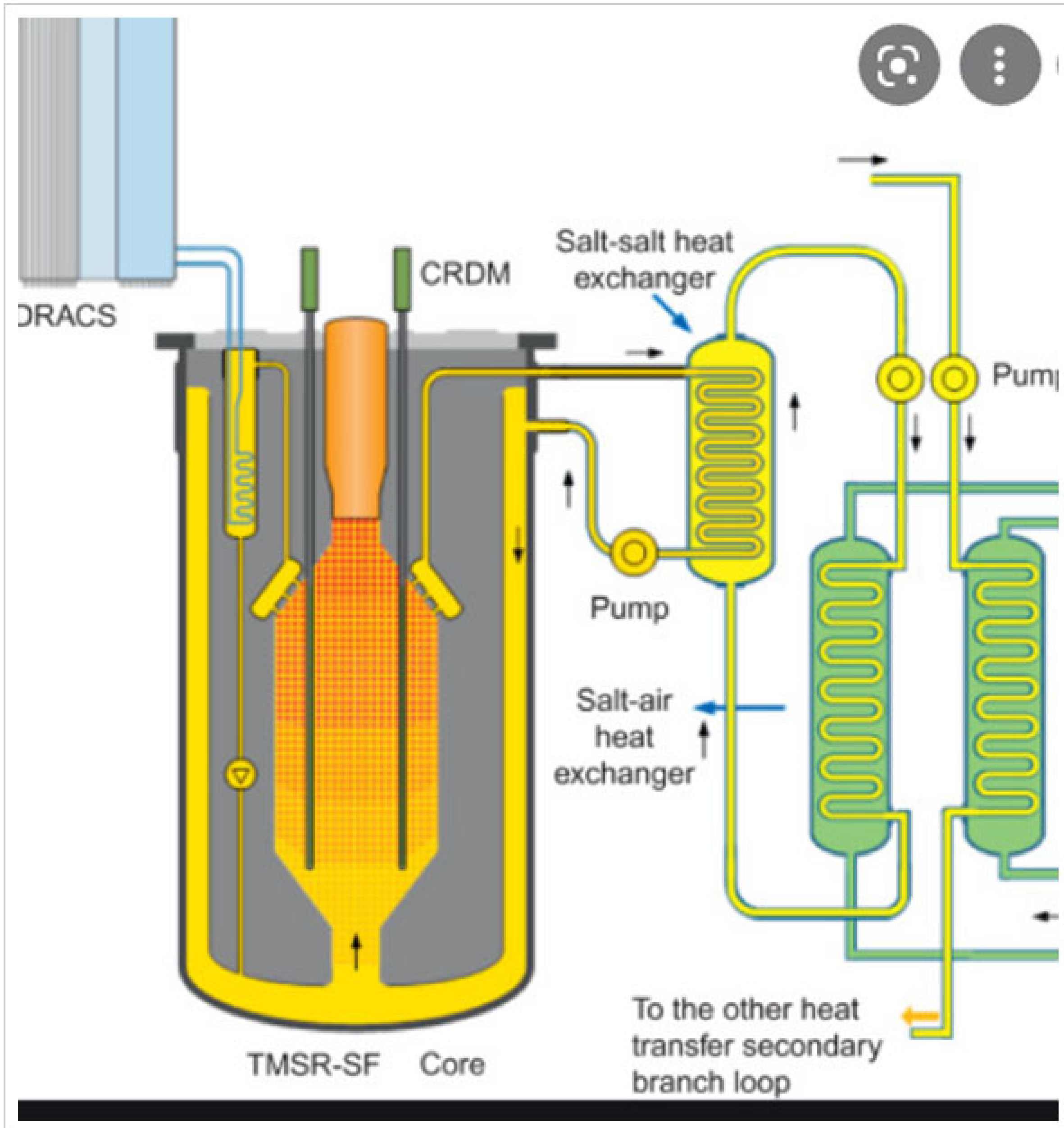


Image: [Thorium molten salt reactor nuclear energy system (TMSR)](#)
Zhimin Dai – Shanghai Institute of Applied Physics (SINAP), Shanghai, China

The project is expected to start on a batch basis with some online refueling and removal of gaseous fission products. The reactor will discharge all fuel salt after 5-8 years for reprocessing and separation of fission products and minor actinides for storage. It will proceed to a continuous process of recycling salt, uranium and thorium, with online separation of fission products and minor actinides. The reactor will work up from about 20% thorium fission to about 80%.

As this type of reactor does not require water for cooling, it will be able to operate in desert regions. The Chinese government has plans to build more across the sparsely populated deserts and plains of western China, complementing wind and solar plants and reducing China's reliance on coal-fired power stations. The reactor may also be built outside China in Belt and Road Initiative nations.

The liquid fuel design is descended from the 1960s Molten-Salt Reactor Experiment at Oak Ridge National Laboratory in the USA. In 2012 the Department of Energy inked a collaboration effort with China on thorium fueled molten salt reactors. (Briefing on the Oak Ridge / China collaboration effort (PDF file 48 pages)

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Terrestrial Energy Signs Agreement to Advance IMSR Deployment in Alberta

- The MOU supports job creation and small modular reactor development in Alberta with a focus on reducing emissions in the oil and gas, and petrochemical industries

Terrestrial Energy, an industry-leading nuclear technology company, and Invest Alberta, the Government of Alberta's crown corporation promoting high-value investments, have signed a Memorandum of Understanding

(MOU) to support commercialization of Terrestrial Energy's Integral Molten Salt Reactor (IMSR) Generation IV small modular reactor (SMR) plant in Alberta.

Terrestrial Energy said in a press statement its IMSR plant "has unique potential to supply the heat and power (cogeneration) needs of many industrial activities, including those in the Alberta oil and gas, and petrochemical sectors."

Under the terms of the Terrestrial Energy MOU, Invest Alberta will work with Terrestrial Energy on federal and provincial policies, and industrial incentives supporting transformative energy innovation in the province. Alberta is one of four provinces working to advance SMR technologies through an interprovincial memorandum of understanding.

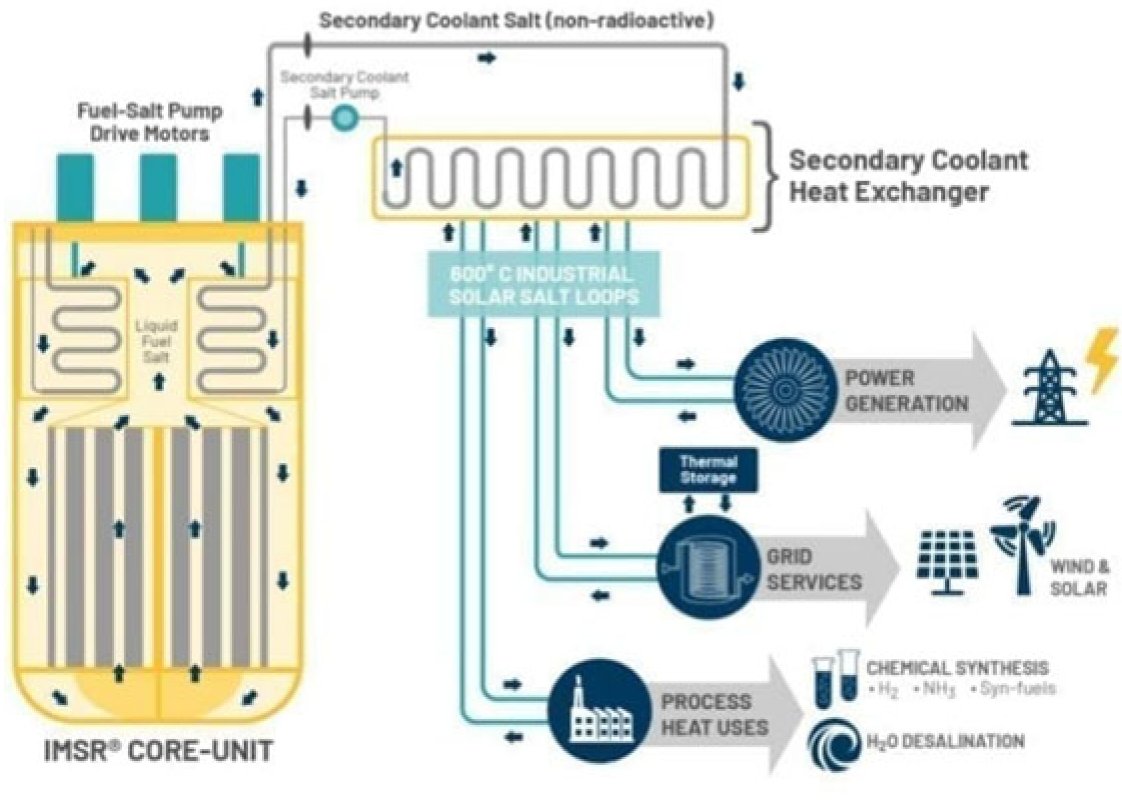
Terrestrial Energy's said its IMSR plant is intended to supportr natural resource extraction, low-carbon hydrogen and ammonia production, as well as other energy-intensive industrial activities.

Terrestrial Energy said it anticipates supporting high-quality jobs as it expands its activities in western Canada. Terrestrial Energy has previously invested over $100 million in its Ontario operation, where it employs more than 100 personnel.

About the Terrestrial Energy IMSR

Terrestrial's 195-MWe IMSR power plant is a thermal-spectrum, graphite-moderated, molten-fluoride-salt reactor system that uses standard-assay low-enriched uranium (less than 5% U-235) fuel. In the integral process—which takes place within the "Core-unit"—the fuel salt is diluted with coolant salt (consisting of fluorides such as sodium fluoride, beryllium fluoride, and/or lithium fluoride), and the mixture serves both as fuel and primary coolant.

The mixture is pumped between a critical, graphite-moderated (thermal spectrum) core, and then through the integral heat exchangers to transfer its heat to the external secondary coolant salt loop.



The Replaceable IMSR® Core-unit

The secondary loop consists of bare diluent salts (without fuel salt added), and it, in turn, transfers its heat to another intermediate nitrate salt loop, which essentially serves as a barrier between the radioactive primary components and the end-users. The nitrate salt–heated steam generator finally produces steam that can be used for power generation or industrial applications.

Brief History of Reactor Design Efforts Related to Tar Sands

The Terrestrial Energy MOU is the latest in a long series of proposals to use nuclear reactors to supply process heat for the tar sands oil extraction companies in Alberta. As long ago as the mid-1980s there were proposals for larges and small reactors to do the job. Terrestrial Energy's small size, and therefore more affordable cost, may give the firm aa competitive path forward whereas other full size reactor efforts have failed. Here are two examples.

Energy Alberta – More than a decade ago, Atomic Energy Canada Limited (AECL), then a state owned enterprise, proposed to build two 1,000 MWe advanced CANDU type reactors in northern Alberta for this purpose.

Power from the reactors would be used in oil sands extraction, which uses large volumes of steam to soften and recover oil from the gritty mixtures of bitumen. Canada has huge reserves of oil sands but recovery of the oil is energy intensive – natural gas can account for up to 60% of operating costs at current recovery facilities, not to mention the associated carbon emissions.

The proposal never got off the ground being rejected by the oil companies as too expensive and with a time line that far exceeded their capital requirements planning horizons. These two factors remains the main challenges for nuclear reactor developers pitching the use of their designs for the tar sands region.

NGNP – In 2011 the Idaho National Laboratory published an updated study of the prospects for the use of nuclear reactors to provide process heat for tar sands operations. Developed as part of the now defunct Next Generation Nuclear Plant project, it had the following parameters.

The Next Generation Nuclear Plant (NGNP) was expected to be a demonstration of the technical, licensing, operational, and commercial viability of high temperature gas-cooled reactor (HTGR) technology for the production of process heat, electricity, and hydrogen.

A key partner for the Next Generation Industry Alliance was Dow Chemical which wanted to swap out its enormous use of fossil fuels for process heat with a nuclear reactor. (NGNP Briefing – [PDF file 17 slides])

Its nuclear-based technology was intended to provide high temperature process heat (up to 950°C) that can be used as a substitute for the burning of fossil fuels for a wide range of commercial applications.

The substitution of the HTGR for burning fossil fuels would conserve these hydrocarbon resources for other uses, reduces uncertainty in the cost and supply of natural gas and oil, and eliminates the emissions of greenhouse gases attendant with the burning of these fuels.

The NGNP 500 MWt HTGR was pitched a passively safe nuclear reactor concept with an easily understood safety basis that permits substantially reduced emergency planning requirements and improved siting flexibility compared to other nuclear technologies. There were four competing design alternatives for the NGNP reactors. See Table below.

Table 1 Summary of preconceptual design operations and configurations.

Item	Recommended Operating Conditions & Plant Configuration		
	Westinghouse	AREVA	General Atomics
Power Level, MWt	500 MWt	565 MWt	550 – 600 MWt
Reactor Outlet Temperature, °C	950°C	900°C	Up to 950°C
Reactor Inlet Temperature, °C	350°C	500°C	490°C
Cycle Configuration	Indirect – Series hydrogen process and power conversion	Indirect – Parallel hydrogen process and power conversion	Direct PCS Parallel indirect hydrogen process
Secondary Fluid	He	He-Nitrogen to PCS He to H2 Process	He
Power Conversion Power	100% of reactor power	100% of reactor power	100% of Reactor Power
Hydrogen Plant Power	10% of reactor power	10% of reactor power	5 MWt – HTE 60 MWt – S-I
Reactor Core Design	Pebble Bed	Prismatic	Prismatic
Fuel	TRISO UO2 1st and subsequent cores	TRISO UCO – 1st and subsequent cores	TRISO UO2 1st Core Variable subsequent cores
Graphite	PCEA & NBG-18	NGG-17 and NBG-18	IG-110 & NBG-18
RPV Design	Exposed to the gas inlet temperature	Exposed to the gas inlet temperature; insulation and vessel cooling options may be pursued	Exposed to the gas inlet temperature
RPV Material	SA508/533	9Cr – 1Mo	2-1/4 Cr – 1Mo 9 Cr – 1 Mo
IHX	2- Stage Printed Circuit Heat Exchanger (PCHE), In 617 material	PCS – 3 - Helical Coil Shell & Tube, In 617 Process – PCHE or Fin-Plate, In 617	Process – single stage PCHE, In 617
Hydrogen Plant	Hybrid thermo-chemical plus electrolysis	Initial –High Temperature Electrolysis Longer Term – Sulfur-Iodine	Initial –High Temperature Electrolysis Longer Term – Sulfur-Iodine
Power Conversion	Rankine; standard fossil power turbine generator set	Rankine; standard fossil power turbine generator set	Direct gas turbine Option -- Direct Combined Cycle

Tar Sand Applications

At the Idaho National Laboratory a technical evaluation (TEV) was prepared in 2011 as part of a study for the Next Generation Nuclear Plant (NGNP) Project to evaluate the integration of high-temperature gas-cooled reactor (HTGR) technology with conventional chemical processes. This TEV addresses the integration of HTGR heat and power into oil sands recovery via steam assisted gravity drainage (SAGD); specifically, the technical and economic feasibility of the HTGR integration.

The following conclusions were drawn when evaluating the nuclear-integrated SAGD process versus the conventional process:

- Four 600 MWt HTGRs are required to support production of steam and power for a 190,000 barrel per day SAGD facility.
- Nuclear-integration decreases natural gas consumption by up to 100% using HTGR generated steam as the heat source, eliminating 192.5 MMSCFD of natural gas usage.
- Nuclear-integration also eliminates almost 12,000 tons per day of CO_2 production from the SAGD process, as natural gas combustion is eliminated.

Pre-licensing discussions at the NRC regarding the NGNP were suspended in 2013 after a DOE decision in 2011 to not proceed into the detailed design and license application phases of the NGNP Project. DOE's decision reportedly cited impasses between DOE and the NGNP Industry Alliance in cost sharing arrangements for the public-private partnership required by Congress. The project ended in 2015.

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Deep Isolation and Amentum Form Partnership to Commercialize Nuclear Waste Disposal Technology

Deep Isolation Inc. and Amentum have signed a Memorandum of Agreement (MOU) to work together to further the commercialization of Deep Isolation's technology on a global basis. The agreement is intended to position the companies as global leaders in a multi-billion-dollar nuclear waste disposal industry.

Initial target markets for joint work include countries in Europe and the Pacific for geologic disposal of spent fuel and high-level waste.

There is a new sense of urgency to dispose of nuclear waste. Low-carbon nuclear energy is a powerful alternative to fossil fuels in the fight against climate change, but much of the world is requiring a waste solution to be in place before investments are made in new nuclear power installations.

The agreement provides Amentum with access to more than 50 proprietary Deep Isolation inventions, engineering specifications, and know-how. A key item is Deep Isolation's detailed and compliant process based on IAEA guidance for tailoring a deep borehole repository to the specific regulatory requirements, waste inventory, stakeholder needs and local geology of each client.

Deep Isolation said in its press statement that its advanced nuclear technology leverages directional drilling practices to safely and efficiently isolate waste deep underground in borehole repositories, providing many countries with an alternative to a traditional mined repository.

Deep Isolation offers licenses that allow nuclear industry firms access to its protected intellectual property. The program features access to Deep Isolation's patents and engineering work, as well as planning and operational processes that could be used independently of Deep Isolation technology.

“The world is changing fast, and it’s imperative for the success of nuclear energy that we solve the nuclear waste challenge,” said Deep Isolation CEO Elizabeth Muller, an environmentalist and co-founder of the company.

“Deploying the solution requires a large-scale team effort. We are excited to work with Amentum to bring this solution to market,” Muller said. “We are pleased at the value they are placing in Deep Isolation’s solution by investing in this license.”

Amentum, a premier global technical and engineering services provider, brings numerous proven strengths: maintaining complex and high hazard facilities and processes; delivering environmental solutions to customers worldwide; and capabilities in environmental management and waste management.

“Amentum has unparalleled engineering expertise and experience in the use of science and advanced technologies to successfully clean up highly complex nuclear sites,” said Jim Blankenhorn, Senior Vice President of Amentum.

“This partnership strengthens our collective position in a growing market to provide innovative solutions for nuclear disposal around the world.”

After just four years as a public-facing company, Deep Isolation’s milestones include: work with a dozen countries across three continents; a subsidiary in Europe; the acquisition of Freestone Environmental Services; and recently, two multi-million awards from the U.S. Government.

About Deep Isolation

Deep Isolation is an innovator in nuclear waste storage and disposal solutions. The company's patented solution of advanced nuclear technologies will enable global delivery through its partnerships with industry leaders as well as flexible IP licensing options.

About Amentum

Amentum is a global technical and engineering services partner supporting programs of national significance across defense, security, intelligence, energy, and environment. The company has vast experience in the nuclear cleanup market with a successful track record in reducing risk and solving waste management challenges around the world.

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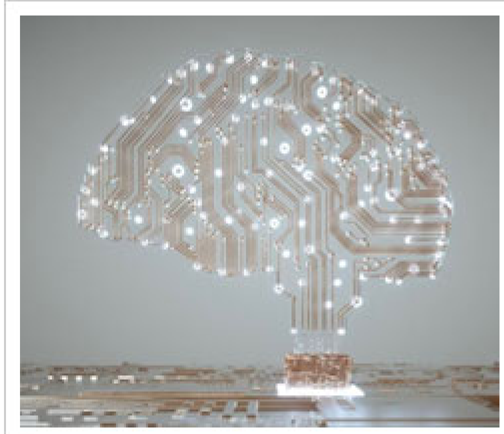
Argonne National Lab Aims to Lower Nuclear Energy Costs with Artificial Intelligence



Nuclear power plants provide large amounts of electricity without releasing planet-warming pollution. But the expense of running these plants has made it difficult for them to stay open.

If nuclear is to play a role in the U.S. clean energy economy, costs must come down. Scientists at the U.S. Department of Energy's (DOE) Argonne National Laboratory are devising systems that could make nuclear energy more competitive using artificial intelligence.

Nuclear power plants are expensive in part because they demand constant monitoring and maintenance to ensure consistent power flow and safety. Argonne is midway through a $1 million, three-year project to explore how smart, computerized systems could change the economics.

"Operation and maintenance costs are quite relevant for nuclear units, which currently require large site crews and extensive upkeep," said Roberto Ponciroli, a principal nuclear engineer at Argonne.

"We think that autonomous operation can help to improve their profitability and also benefit the deployment of advanced reactor concepts."

The project, funded by the DOE Office of Nuclear Energy's Nuclear Energy Enabling Technologies program, aims to create a computer architecture that could detect problems early and recommend appropriate actions to human operators. Ponciroli and colleagues estimate the technology could save the nuclear industry more than $500 million a year.

A typical nuclear plant can hold hundreds of sensors, all of them monitoring different parts to make sure they are working properly.

"In a world where decisions are made according to data, it's important to know that you can trust your data," Ponciroli said. "Sensors, like any other component, can degrade. Knowing that your sensors are functioning is crucial."

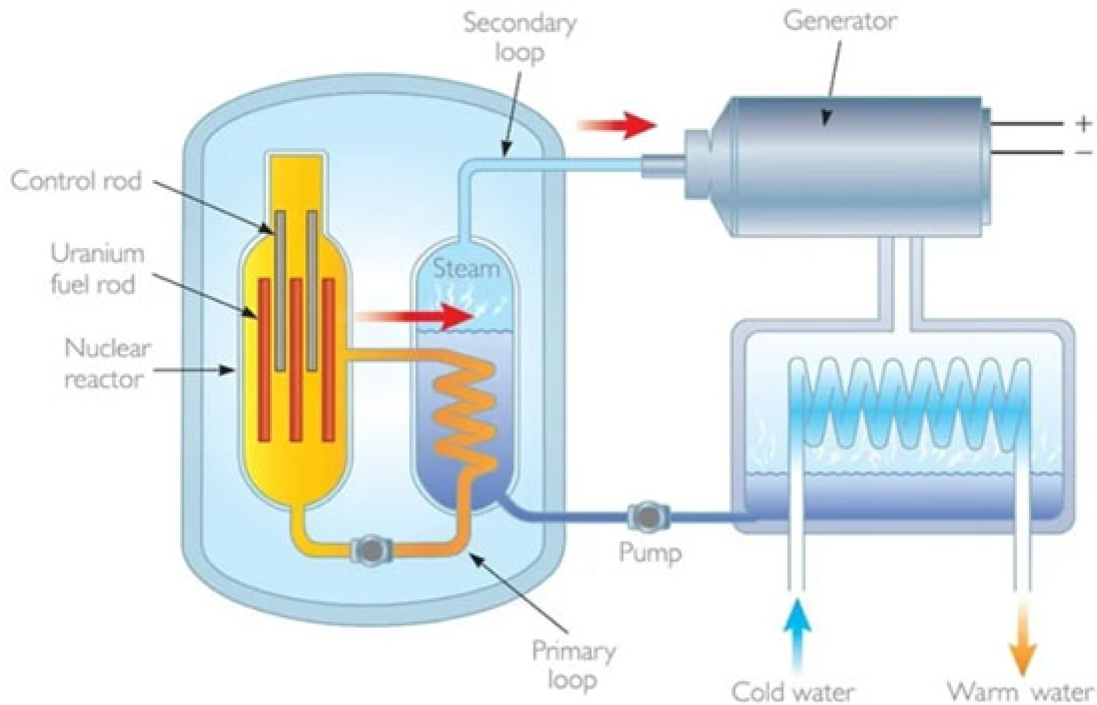
The job of inspecting each sensor—and also the performance of system components such as valves, pumps, heat exchangers—currently rests with staff who walk the plant floor. Instead, algorithms could verify data by learning how a normal sensor functions and looking for anomalies. Having validated a plant's sensors, an artificial intelligence system would then interpret signals from them and recommend specific actions.

"The lower-level tasks that people do now can be handed off to algorithms," said Richard Vilim, an Argonne senior nuclear engineer. "We're trying to elevate humans to a higher degree of situational awareness so that they are observers making decisions."

Four Types of Nuclear Sensors

(Courtesy of AZO Sensors) Nuclear Reactor Sensors are critical to nuclear safety and can be classified into four categories.

- Nuclear sensors measure the parameters of the nuclear chain reaction, such as neutron flux density, thus providing information about the reactor power.
- Process sensors are used to monitor non-nuclear processes, such as reactor coolant pressure, temperature and flow, containment pressure, and others.
- Radiation monitoring sensors for monitoring radiation levels in coolant lines, gas effluents, and the environment around the reactor.
- Special sensors that monitor seismic activity, vibration, hydrogen concentration, water conductivity, and many others.



Reference and Further Reading

INTERNATIONAL ATOMIC ENERGY AGENCY (2011) Core Knowledge on Instrumentation and Control Systems in Nuclear Power Plants, IAEA Nuclear Energy Series No. NP-T-3.12, IAEA, Vienna. (download link)

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Studsvik Scandpower and Blue Wave AI Labs in Partnership to Deliver Next Generation Accuracy to Nuclear Power Analytics

Studsvik Scandpower, Inc. is pleased to announce a strategic partnership with Blue Wave AI Labs to deliver enhanced diagnostic and predictive capabilities to nuclear energy facilities around the globe. The partnership will create a growing product line for Studsvik Scandpower.

Using Studsvik Scandpower's state-of-the art codes, CASMO5 and SIMULATE5, coupled with Blue Wave's innovative cloud-based Nuclear-AI Platform, plant operators will improve plant predictions, reduce operational challenges, and increase the efficiency of core design and cycle management in a direct way. According to the press statement the collaboration is expected to provide visibility into the fuel cycle will allow operators to reclaim unnecessary design margin, reduce reload fuel costs, and eliminate potential lost generation revenue.

CASMO5 is Studsvik Scandpower's state-of-the-art 2D lattice physics code for modeling square and hexagonal LWR nuclear fuel. SIMULATE5 is a 3D, steady-state, multi-group nodal code for the analysis of LWRs delivering vendor independence and unparalleled accuracy.

Blue Wave AI Labs' Nuclear-AI Platform components have been recognized by the Nuclear Energy Institute with a 2021 Top Innovative Practice (TIP) award. The prestigious award in the nuclear fuel category recognizes creative ideas that have substantial impact on improving the safety and reliability of nuclear energy.

"Blue Wave has proven to be the trusted leader in AI solutions for the nuclear industry, already serving over half the U.S. domestic fleet of boiling water reactors and making a significant difference in their operational efficiency," says Rob Whittle, President and CEO of Studsvik Scandpower.

"Partnering with Blue Wave AI Labs brings enhanced value to the Studsvik Scandpower offerings and allows us to continue to meet our brand promise of always being state-of-the-art while delivering advanced solutions to our international customers."

"We are proud to partner with the worldwide leader in commercial neutronics software to deliver enhanced product offerings and services around the globe," says Tom Gruenwald, Senior Vice President at Blue Wave AI Labs.

"This partnership with Studsvik Scandpower will broaden the reach of our AI-based analytical tools to the international marketplace and accelerate the development of revolutionary analytical techniques necessary for next generation nuclear power systems."

Nuclear energy providers are being increasingly pressured by market changes to decrease costs while maintaining, and if possible, increasing production revenue. The Studsvik Scandpower and Blue Wave AI Labs strategic partnership brings together simulation capabilities with advancements in artificial intelligence and machine learning to enable new levels of provider competitiveness.

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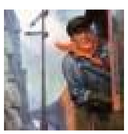

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